Modern Concepts of Cardiovascular Disease

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THE DEVELOPMENT OF THE HEART

EDITORIAL NOTE:

The review of the development of the heart by Dr. Saunders will be of practical value as immediate reference in the forthcoming issues on Congenital Heart Disease by Dr. Maude E. Abbott. In that Cunningham's Anatomy is generally available, we may suggest that the descriptions of Dr. Saunders be followed in correlation with the clear diagrams presented in that volume on pages 26-34, 1040-1046 and 1057 of the sixth edition, 1931 (Robinson).

Part I

IN THE ensuing short article measurements, age at which changes occur, etc., have been omitted in order to give as briefly as possible, a continuous and connected account of the main features of the development of the heart. These may be simply and speedily ascertained by consulting any standard text-book of embryology.

In order to follow the various stages in the development of the heart and pericardium it is first of all necessary to examine the origin and arrangement of the permanent mesoderm at that period when the human embryo is a bivesicular structure. At this stage the embryonic area is the area of contact between the ectodermal vesicle enclosing the cavity of the amnion and the entodermal vesicle or achenteron, the future alimentary system. As growth continues, the embryonic area or plate becomes more elongated and a linear streak, *the primitive streak*, appears in its long axis. The primitive streak gives origin to the permanent mesoderm and extends forwards between the two vesicles from in front of the body stalk attaching the embryo to the surrounding trophoblast. From the primitive streak by a process of budding and proliferation mesodermal cells pass marginally between the vesicles to the periphery. The anterior end of the primitive streak or head process continues its forward extension whilst the more lateral mesoderm by continued proliferation is carried forwards and outwards. In the meantime the longitudinal axis of the embryo is completed by the formation in the overlying ectoderm of a groove, the *neural groove*, and lateral plates, the *neural plates*, which represent the rudiments of the central nervous system.

CARDIAC AREA AND PERICARDIUM

The permanent mesoderm is now arranged in the following fashion. In the long axis of the embryonic shield lies the primitive streak with its forward extension or head process. About this central axis the mesoderm lies as a U-shaped sheet. The two limbs of the U-parallel the central axis and the bight connecting the limbs crosses the mid-line in the anterior margin of the embryonic plate, some little distance in front of the extremity of the head process. This portion of the mesoderm connecting the lateral limbs is the *cardiogenic plate.*

Behind (caudal) to the cardiogenic plate, between it and the anterior extremity of the head process is a small interval free of mesoderm, the *bucco-pharyngeal area*, where the ectodermal and entodermal vesicles make direct contact.

The *pericardial cavity* is formed by the fusion of a number of vesicular spaces which develop in the substance of the mesoderm of the cardiogenic plate. In a similar manner cleavage spaces appear in the lateral sheets of mesoderm, the intra-embryonic coelom or future pleural and peritoneal cavities. Backward extension of the pericardial cavity on either side links up the coelomic cavities, the whole now forming a U-shaped cavity. Rapid expansion of the pericardial cavity results in the relative constriction of the U-shaped tube on either side at the point of junction of pericardial and lateral clefts. This is the *pleuropericardial canal.*

At a slightly later period the rapid growth of the embryonic area causes the structure to buckle as a whole over the underlying entodermal vesicle. The cardiogenic plate with its enclosed cavity is in consequence carried over the anterior margin from its dorsal position and the pericardial cavity is now ventrally placed, ventral to what is now the foregut. The bucco-pharyngeal area originally behind the cardiogenic area is now recognized as occupying the anterior extremity of the embryo.

The caudal wall of the transposed pericardium thickens until it forms a considerable mass of tissue, a mass which constitutes a septum in front of the now relatively constricted lower vesicle. In this way arises *the septum transversum*, separating the pericardial and body cavities, which will form a major part of the adult diaphragm and into which the liver buds grow and undergo development.

THE PRIMITIVE CIRCULATION

The mesodermal cells on the surface of the yolk sac proliferate early, producing collections of vasoformative or angioblastic cells. These cells by the fusion of isolated groups give rise to solid plexuses within which lumina develop containing plasma and primitive blood corpuscular elements. Such groups constitute the so-called *blood islands* of Pander.

The blood islands, at first isolated, soon join with one another producing a network of primitive vessels on the surface of the yolk sac. Other vessels arise in much the same manner in the body stalk and chorion and a little later in the body of the embryo. The junction of these several systems establishes the components of a primitive circulation.

The primitive stem vessels are now recognized as being arranged in the following manner:

From the chorionic plexus an unpaired venous trunk, the *vena umbilicalis impar*, passes forwards in the body stalk. This vein bifurcates into the *right and left umbilical veins* which extend to the cardiogenic area. The umbilical veins are joined at their anterior ends by veins, the *vitelline veins*, which have arisen from the plexus on the surface of the yolk sac. The umbilical veins and their tributaries reach the cardiogenic plate in the region of the future septum transversum and end by connecting with a short single vessel (initially double), the *primitive heart.*

The primitive heart, dorsal in position, extends back to the bucco-pharyngeal area where it divides into the two *primitive aortae*, which pass one on either side of the bucco-pharyngeal area. These course caudally and turn down as the *primitive umbilical arteries* to the body stalk, by means of which they are carried back to the chorion.

Reversal of the pericardium and further growth of the embryo bring about a number of important changes. The primitive short cardiac tube is now transposed ventrally together with the pericardial cavity. The rapidly elongating cardiac tube at the same time commences to invade the pericardial cavity on the dorsal aspect, carrying with it a mesentary, the *mesocardium.*

The anterior ends of the umbilical and vitelline veins occupying the septum transversum, are recognized as terminating in the now caudal extremity of the cardiac tube.

The anterior segments of the primitive aortae have become involved in the buckling process so that three parts can be defined; a short ventral segment, the *ventral aorta;* the bend which runs along the side of the bucco-pharyngeal area, the *first aortic arch;* and the remaining dorsal part which is the *dorsal aorta.*

As growth continues additional vessels make their appearance. Lateral to each dorsal aorta a venous channel, the *postcardinal vein*, now runs forwards to the septum transversum where it is joined by a vein, the *precardinal*, from the developing head end of the embryo. The union of precardinal and postcardinal veins forms a short common trunk, the *duct of Cuvier*, which closely related to the pleuropericardial canal, passes into the septum transversum where it opens into the caudal extremity of the cardiac tube, together with the umbilical and vitelline veins.

A further series of aortic arches, five pairs in number, develop successively in association with the pharyngeal region so that a total of six such pairs are formed.

THE HEART

The heart has appeared as a single short tube in the cardiogenic area and with reversal of the pericardium is found in the roof of the pericardial cavity where it is suspended by a mesentery, the mesocardium. The mesocardium, intact for a short time, disappears in part and an aperture, the *transverse sinus of the pericardium*, now makes its appearance, connecting the right and left halves of the cavity.

Rapid elongation of the cardiac tube between two relatively fixed extremities, results in the structure becoming bent upon itself to form a loop. This loop begins to show a series of constrictions, subdividing it into a series of primary chambers. These are from behind forwards, the sinus venosus, the atrium, the ventricle, the bulbus cordis and the aortic trunk. The cardiac loop extends from the septum transversum caudally, where it receives the paired umbilical veins, the vitelline veins and the ducts of Cuvier, opening into the sinus venosus, to the aortic trunk, cranially, where the two ventral aortae are given off. The ventricle is found occupying the summit of the loop.

Further elongation of the heart, and unequal growth in its various parts, exaggerates the initial bend and results in important modifications. Its cranial and caudal extremities are approximated to assume their position of permanent fixation within the pericardium. The sinus venosus, at first within the septum transversum, is now somewhat projected into the pericardial cavity. The cardiac tube already bent upon itself ventrally in its long axis, is now also folded transversely. The caudal limb of the loop consisting of sinus venosus and atrium passes to the left and enters the ventricle which occupies the summit of the loop. The cranial limb, formed by the bulbus cordis and aortic trunk hinges back on the ventricle to the right.

The atrium expands largely at the expense of the right segment of the sinus venosus and as it does so it commences to embrace on either side the bulbus cordis and aortic trunk. The ventricle also enlarges with great rapidity and commences to show surface evidence of its division into two cavities. The bulbus cordis is partly absorbed into the ventricle and partly into the aortic trunk which latter is dividing into the stems of the pulmonary artery and aorta.

The right duct of Cuvier is giving rise to the superior vena cava and a new formation, to the inferior vena cava, whilst the left umbilical vein persists for a time as the ductus venosus.

Having discussed these surface changes, the next section will take up the changes which occur within the cavities of the heart.

(*To be continued*)

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